

PATENT CLAIMS

1. A method of cooling a cabinet (50) containing heat dissipating electronic components (PBA), comprising the steps of:
- 5 - circulating cooling medium in a closed fluid system to absorb heat in an evaporator (13; 113; 213) in the cabinet and to transfer the absorbed heat from the cabinet and to emit said heat outside the cabinet in a condenser/heat exchanger (14),
 - detecting the evaporator temperature (T_1) inside the cabinet to determine the heat load on the system;
 - 10 - detecting the ambient temperature (T_3) and the temperature (T_2) in the condenser to determine the conditions of the heat transfer from the cooling medium;
 - controlling a forced circulation of the cooling medium based on the detected heat load and conditions of heat transfer;
 - controlling the flow of the cooling medium back to the evaporator in the cabinet based on
15 the detected heat load and conditions of heat transfer; and
 - controlling the activation/deactivation of a vapor compression cycle based on the detected heat load and conditions of heat transfer;
- thereby allowing a controlled shifting between cooling of the cabinet in different cooling modes optimized for different heat load and heat transfer conditions.
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2. A method according to claim 1, **characterized in** that when the detected heat load inside the cabinet (50) is lower than a predetermined first level and/or the detected ambient temperature (T_3) is lower than a predetermined level,
- a fluid pump (12) is deactivated for interrupting forced circulation of the cooling medium;
 - 25 - the full flow of cooling medium from the condenser (14) is returned to the evaporator (13; 113; 213) where cooling medium is vaporized; and
 - the full flow of vaporized cooling medium from the evaporator (13; 113; 213) is conducted to a secondary side (26, 27) of an ejector (11), through the ejector and from an outlet (28, 29) from the ejector back to the condenser;
- 30 whereby the cooling of the cabinet is performed in a thermosyphon cooling mode.

3. A method according to claim 2, **characterized in** that the level of the ambient temperature (T_3) is approximately 30°C, in that cooling medium is vaporized at approximately 50°C in the evaporator (13; 113; 213), and in that the cooling medium vapor condenses at substantially the same temperature in the condenser (14) and emits heat, whereby the temperature
5 gradient between the surroundings and the condenser is in the range of 15-30°C.
4. A method according to claim 2 or 3, **characterized in** that the cooling medium vapor from the evaporator (13; 113; 213) is drained freely through the ejector (11) and is condensed in the condenser (14).
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5. A method according to any of claims 1-4, **characterized in** that when the detected heat load inside the cabinet (50) is higher than a predetermined first level but lower than a predetermined second level and the detected ambient temperature (T_3) is lower than a predetermined level,
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- a fluid pump (12) is activated for performing forced circulation of the cooling medium;
 - the full flow of cooling medium from the condenser (14) is returned to the evaporator (13); and
 - cooling medium from the evaporator (13; 113; 213) is pumped to a primary side (21, 22) of an ejector (11), through the ejector and to the condenser;
- 20 whereby the cooling of the cabinet is performed in a liquid cooling mode.
6. A method according to claim 5, **characterized in** that the level of the ambient temperature (T_3) is approximately 30°C, in that a portion of the cooling medium vaporizes at approximately 50°C in the evaporator (13; 113; 213) and in that cooling medium vapor condenses at
25 substantially the same temperature in the condenser (14) and emits heat, whereby a temperature gradient between the surroundings and the condenser is in the range of 15-30° C.
7. A method according to claim 5 or 6, **characterized in** that entrance to a secondary side (26, 27) of the ejector (11) is blocked and in that the full flow of cooling medium in a liquid
30 and a vapor phase is pumped through the ejector primary side (21, 22) to the condenser (14).

8. A method according to any of claims 1-7, **characterized in** that when the detected heat load inside the cabinet (50) exceeds a predetermined second level and/or the detected ambient temperature (T_3) is higher than a predetermined level,
- a fluid pump (12) is activated for performing forced circulation of the cooling medium;
 - 5 - a restricted flow of cooling medium is conducted from the condenser (14) to the evaporator (13; 113; 213) where the cooling medium is vaporized, the restricted flow being controlled based on the detected evaporator temperature (T_1) and/or on the detected ambient temperature (T_3);
 - the remainder of the flow of cooling medium from the condenser is circulated to a primary
 - 10 side (21, 22) of an ejector (11) by the fluid pump, creating a negative pressure at a secondary side (26, 27) of the ejector; and
 - the vaporized cooling medium is pumped out from the evaporator (13; 113; 213) to the secondary side (26, 27) of the ejector by the created negative pressure and is returned to the condenser;
 - 15 whereby the cooling of the cabinet is performed in an ejector cooling mode.
9. A method according to claim 8, **characterized in** that the pressure delivered by the fluid pump (12) is controlled based on the detected evaporator temperature (T_1) and/or on the detected ambient temperature (T_3).
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10. A method according to claim 8 or 9, **characterized in** that the vaporized cooling medium is compressed and partly condensed in the ejector (11) by the pumped primary cooling medium, and is then conducted to the condenser (14) for further condensation.
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11. A method according to any of claims 8-10, **characterized in** that a pressure difference (P_1-P_2) and a temperature gradient (T_1-T_2), respectively, between evaporator (13; 113; 213) and condenser (14) is regulated by controlling a restrictor valve (18) to provide optimal cycle conditions in relation to the detected heat load and ambient temperature (T_3).
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12. A cooling system (10) for cooling a cabinet (50) containing heat dissipating electronic components (PBA), comprising:

- means (12) for circulating a cooling medium in a closed fluid system from a condenser/heat exchanger (14) to an evaporator (13; 113; 213) inside the cabinet and back to the condenser/heat exchanger (14);
- at least one valve (15-17) for controlling the flow of cooling medium between the condenser and the evaporator;
- an ejector (11) having a primary (21, 22) and a secondary (26, 27) side;
- a fluid line system (40) connecting the condenser (14) to the evaporator (13; 113; 213) and to a fluid pump (12), respectively, through first and second controlled valves (18, 17, respectively) and connecting the evaporator to the fluid pump and the ejector secondary side, respectively, through third and fourth controlled valves (15, 16, respectively);
- temperature sensors (30, 31, 32) for detecting the evaporator temperature (T_1), for detecting the condenser temperature (T_2) and for detecting the ambient temperature (T_3), respectively; and
- a control unit (19) for controlling the positions of the valves in dependence on the detected temperatures.

13. A cooling system (10) according to claim 12, **characterized in** that the first valve (18) is a one-way restrictor valve blocking backflow from the evaporator (13; 113; 213) to the condenser (14) and controlled by the control unit (19) to regulate cooling medium flow from the condenser to the evaporator.

14. A cooling system (10) according to claim 12 or 13, **characterized in** that the ejector (11) is a low pressure ejector operating at low primary side positive pressure and having a primary side distribution chamber (21) for receiving the primary cooling medium and a multi-channel nozzle (23) in the form of a spherical segment provided with radial nozzle holes (23A) leading into a mixing chamber (24) that is surrounded by a secondary cooling medium supply chamber (26) communicating with the mixing chamber through a plurality of supply holes (25) and that is connected to a diffuser (29) through a neck (28).

15. A cooling system (10) according to claim 14, **characterized in** that the cooling medium conducting inner cross-section area of the neck (28) is substantially equal to the total cross-section area of the nozzle holes (24) and in that the geometrical centre (C) of the spherical

segment of the nozzle (23) lies on a mixing chamber center axis (CA), immediately downstream of the neck (28).

16. A cooling system (10) according to any of claims 12-14, **characterized in** that the
5 evaporator (13) consists of several evaporator heat sinks (13A) each directly contacting one or more of the electronic components (PBA).

17. A cooling system (10) according to claim 16, **characterized in** that the evaporator (13)
consists of thin metal plates (13A) with built-in water channels directly transferring heat from
10 the electronic components (PBA).

18. A cooling system (10) according to any of claims 12-15, **characterized in** that the
evaporator (113) comprises a cold wall (114) containing cooling medium and contacting one
edge of several electronic components (PBA) and in that heat transfer from the electronic
15 components to the cold wall cooling medium is performed through heat lines, heat pipes or
aluminum plates (115).

19. A cooling system (10) according to any of claims 12-15, **characterized in** that the
evaporator (213) has an evaporator chamber (214), and in that the ejector (11) is integrated as
20 a unit with the evaporator chamber (214).

20. A cooling system (10) according to claim 19, **characterized in** that the diffuser (29) of
the ejector (11) is physically connected to the condenser (14).

25 21. A cooling system (10) according to claim 20, **characterized in** that ejector, condenser
and evaporator chamber are one integrated unit.
